TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 570

EFFECT OF CHANGES IN TAIL ARRANGEMENT UPON THE SPINNING OF A LOW-WING MONOPLANE MODEL

By C. H. Zimmerman
Langley Memorial Aeronautical Laboratory

Washington
June 1936

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 570

EFFECT OF CHANGES IN TAIL ARRANGEMENT UPON THE SPINNING OF A LOW-WING MONOPLANE MODEL

By C. H. Zimmerman

SUMMARY

A series of tests was made in the N.A.C.A. free-spinning tunnel to find the effect upon spinning characteristics of systematic changes in tail arrangement. The tests were made with a 1/16-scale model of a low-wing monoplane of modern design. The changes consisted of: (1) variation of the fuselage length; (2) variation of the fore-and-aft location of the vertical surfaces; and (3) variation of the vertical location of the horizontal surfaces.

The spinning characteristics of the model, including the number of turns required for recovery, were found to vary systematically and regularly with systematic changes in the tail arrangement. The following changes in tail arrangement had harmful effects upon the recovery characteristics (which originally were excellent): (1) shortening the fuselage; (2) placing the vertical surfaces directly above the horizontal surfaces as compared with locations either fore or aft of this position; (3) moving the horizontal surfaces downward from their original location at the top of the fuselage.

INTRODUCTION

That the arrangement of the tail surfaces has a very important effect upon the spinning characteristics of an airplane is well known, having repeatedly been confirmed by various investigators (references 1 to 7). The practical problem facing designers is to provide an empennage that will offer a maximum of resistance to the type of spin to be expected of the wing and mass combination of the airplane without the sacrifice of other desirable features.

A model of a modern low-wing monoplane undergoing routine tests at the N.A.C.A. free-spinning tunnel was found to have very good characteristics, both during the spin and in recoveries. This model had an unusual tail arrangement (fig. 1). An investigation was undertaken to determine whether the good spinning characteristics resulted from the particular tail arrangement and, if so, which features were primarily responsible. Since this investigation was to be the first to determine the effect of systematic changes of a model in the free-spinning tunnel, it was also expected to indicate the suitability of the tunnel for similar but more extensive research.

The model was tested in its original condition and with systematic changes in tail length, in the fore-and-aft location of the vertical surfaces, and in the vertical location of the horizontal surfaces. Both spins and recoveries were made with two different elevator settings.

APPARATUS AND MODEL

The tests were made in the N.A.C.A. free-spinning wind tunnel in the manner described in reference 7.

The scale of the model was 1/16 that of a modern low-wing monoplane having the following general characteristics:

Wing span - - - - - - - - - - - - - - - - -	42 ft.
Wing area - - - - - - - - - - - - - - - -	305 sq.ft.
Wing section - - - - - - - - - - - - - - -	N.A.C.A. 23012
Ratio of vertical tail area to wing area - - - - - - - - - - - - - - - - - - -	0.07
Ratio of tail length (distance from c.g. to rudder hinge axis) to wing span - - - - - - - - - - - - - - - - - - -	0.48
Gross weight - - - - - - - - - - - - - - -	5,575 lb.
Center-of-gravity location, percentage of mean chord back of leading edge of mean chord - - - - - - - - - - - - - -	27.7 percent

$\frac{A-B}{m b^2} \approx -100$

Moments of inertia:

A (about X axis) - - - - - - - - - 3,350 slug-ft.^{2}

B (about Y axis) - - - - - - - - 7,020 slug-ft.^{2}

C (about Z axis) - - - - - - - - - 9,580 slug-ft.^{2}

Most of the model was of balsawood. The leading and trailing edges and the tips of the wing were reinforced with spruce and bamboo to prevent damage from striking the safety netting. The rear portion of the fuselage was hollowed for longitudinal balance. Sections of the wing were removed to obtain a mass distribution similar to that of the airplane. Ribs were fitted into the cutaway spaces and the wing contour was restored with a covering of silk tissue paper. A clockwork delayed-action mechanism (reference 7) was installed in the model to move the rudder and elevator surfaces during spins. Lead weights were suitably disposed to give the proper total weight and mass distribution.

The original tail arrangement is shown in figure 1. Modifications were made by moving the original surfaces to the positions indicated in figures 2, 3, and 4; it was not possible, however, to preserve smoothly faired contours. It is believed that this lack of fairness had no important bearing upon the inferences to be made from the results obtained. The changes in tail length illustrated in figure 2 were accompanied by appropriate changes in ballast to keep the weight and center-of-gravity position constant, which resulted in changes in moments of inertia of the same order of magnitude as would occur for similar changes to the airplane.

TESTS AND RESULTS

Spins were tried with the rudder 30° with the spin and the elevator 27° up and 20° down with each of the tail arrangements illustrated in figures 2, 3, and 4. For spins with the elevator up, recoveries were made by simultaneous and quick reversal of the rudder and downward movement of the elevator. For spins with the elevator down recoveries were made by quick reversal of the rudder.

The results are given in figures 2, 3, and 4. The number of turns for recovery, the angle of attack, the value of $\Omega b/2V$, the angle of sideslip, the radius, and the vertical velocity, all in terms of equivalent full-scale values, are plotted against change in full-scale tail length in figure 2; against change in horizontal position of the vertical surfaces in figure 3; and against vertical location of the horizontal surfaces in figure 4.

The turns for recovery represent the number of turns after reversal of the rudder and elevator if the elevator was up during the spin and after reversal of the rudder alone if the elevator was down during the spin. The angles of attack and of sideslip refer to the values of these variables at the center of gravity of the airplane.

The precision of the various measurements and the approximations involved in calculating the radius and the angles of attack and of sideslip (see reference 7) were such that the values represented in the figures are believed to be correct within the following limits:

Turns for recovery	1/4 turn
Angle of attack	$\pm 3^\circ$
$\frac{\Omega b}{2V}$	± 3 percent
Angle of sideslip	$\pm 1\text{-}1/2^\circ$
Radius	± 10 percent
Velocity	± 2 percent

EFFECT OF CHANGES IN TAIL LENGTH

Spins were possible with the elevators up with the two shortest tail lengths tried. (See figs. 1 and 2.) With the longer tail lengths the model invariably went into a spiral dive with eventual recovery. The spins obtained with the shortened tail lengths were fairly steep, about 42° angle of attack, with small values of $\Omega b/2V$, large radii, and high vertical velocity.

With the elevators down, spins were obtained with all tail lengths. It is interesting to note that shortening the tail length 16 inches (full scale) had a comparatively small effect on the spin, the two succeeding reductions of 16 inches each had a fairly large effect, and the final reduction again had but small effect. The changes in the spin were as expected; reduction of the tail length resulted in spins with higher angles of attack, higher values of $\Omega b/2V$, smaller radii, and slower rates of descent. There was little change in sideslip with change in tail length or in elevator setting.

The effect upon the recovery of shortening the tail length closely paralleled the effect upon the spin. Recoveries made from spins with the two shortest lengths with the elevator up required only two turns. About two turns were also required for recoveries with the original tail length and elevators down. The number of turns increased to eight when the tail length was shortened 48 inches, but there was little change with the further reduction of 16 inches.

EFFECT OF CHANGES IN THE FORE-AND-AFT LOCATION OF THE VERTICAL SURFACES

No spins were obtained with the elevators up, the model going into a spiral dive in each case.

The fore-and-aft location of the vertical surfaces had a very great effect upon the spinning characteristics when the elevators were down. Movement of the surfaces 8 inches ahead of their original location (see figs. 1 and 3) resulted in very steep spins, angle of attack about 25°, at high rates of descent. These spins were not very stable and it was impossible to get complete records without great risk of wrecking the model. Movement of the surfaces still farther ahead, up to a total displacement of 48 inches, produced no additional difference in the spin sufficiently great to be recognized by the observers.

Movement of the vertical surfaces backward into the shielded region above the horizontal surfaces resulted in flatter spins with corresponding changes in angle of attack, $\Omega b/2V$, radius, and rate of descent but with little change in sideslip. The flattest spins were obtained with the leading edge of the fin just slightly ahead of the leading edge of the stabilizer. Farther backward movement resulted in steeper spins, the rate of change in charactoristics with amount of backward movement being fairly rapid.

The effect of vertical-surface location on recovery was similar but more striking than the effect upon the spin itself. The slowest recoveries, 8 to 20 turns, were obtained with the leading edge of the fin just above the leading edge of the stabilizer. The recovery seemed to depend very critically upon the exact location of the surfaces, and there was considerable scattering of the test points. Movement of the surfaces backward by 8 inches resulted in two-turn to three-turn recoveries. The one recovery made from the very steep spin when the vertical surfaces were ahead of their original location was very rapid and was not repeated because of the previously mentioned great danger of wrecking the model.

EFFECT OF CHANGES IN THE VERTICAL LOCATION OF THE STABILIZER

Although no spins could be obtained with the elevators up when the horizontal surfaces were in their original location, placing these surfaces 8 inches down on the side of the fuselage resulted in spins at 66° angle of attack with corresponding values of the other characteristics. An additional downward movement of 8 inches resulted in very steady, flat spins with an angle of attack of 75°.

When the elevators were down, movement of the horizontal surfaces to a lower position on the fuselage resulted in steadier, flatter spins with corresponding changes in angle of attack, $\Omega b/2V$, radius, and rate of descent. The changes were not so striking as those obtained with the elevators up. There was very little change in angle of sideslip with the elevators either up or down.

Recoveries required about five turns for the spins with elevators up. There was little difference in the turns required for recovery between the two lower locations of the surfaces. With these lower locations recoveries with the elevators down were almost identical with those when the elevator was up.

POINTS OF GENERAL INTEREST

The point brought out most strikingly by this investigation is the consistency and general regularity of the results obtained. Although small variations in tail arrangement in some instances produced very great changes in spinning characteristics, extension of the variations in all cases showed that these apparently abrupt changes were but parts of general trends.

The results are in entire agreement with previous information from many sources. It was found that by certain reasonably small changes in the tail arrangement all of the spinning characteristics, except the amount of sideslip, could be changed through wide ranges. The excellent behavior of the model in its original condition was undoubtedly largely caused by the particular tail arrangement.

This conclusion was also supported by supplementary tests which included interchanging the tail unit of the subject model with that of another low-wing monoplane of approximately the same size. This latter model had very poor spinning characteristics, consistently failing to recover regardless of the control-surface settings or movements. The supplementary tests showed that, when the same tail length was used for each model, interchanging the tail units resulted in a corresponding interchange of spinning characteristics within limits of practical applicability.

The present tests were made with only one loading condition and one wing arrangement. Different wing arrangements and loading combinations tested with the changes in tail arrangement reported herein would have given different quantitative results and might have given, in extreme cases, different qualitative indications. A systematic comprehensive research starting with a typical model and including such changes as conversion from a low-wing to a high-wing monoplane, conversion from a monoplane to a biplane, etc., all considered in the light of comparisons between model and airplane results such as those in reference 7, will be necessary before these data can be applied quantitatively to the spinning behavior of new designs.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 28, 1936.

REFERENCES

1. Irving, H. B., Batson, A. S., and Stephens, A. V.: Spinning Experiments on a Single Seater Fighter with Deepened Body and Raised Tailplane. R. & M. No. 1421, British A.R.C., 1932.

2. Stephens, A. V.: Free-Flight Spinning Experiments with Several Models. R. & M. No. 1404, British A.R.C., 1931.

3. Irving, H. B.: A Simplified Presentation of the Subject of the Spinning of Aeroplanes. R. & M. No. 1535, British A.R.C., 1933.

4. Stephens, A. V., and Francis, R. H.: Model Spinning Tests of an Interceptor Fighter. R. & M. No. 1578, British A.R.C., 1934.

5. Bamber, M. J., and Zimmerman, C. H.: Effect of Stabilizer Location upon Pitching and Yawing Moments in Spins as Shown by Tests with the Spinning Balance. T.N. No. 474, N.A.C.A., 1933.

6. Scudder, N. F., and Seidman, Oscar: A Flight Investigation of the Spinning of the F4B-2 Biplane with Various Loads and Tail Surfaces. T.R. No. 529, N.A.C.A., 1935.

7. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. T.R. No. 557, N.A.C.A., 1936.

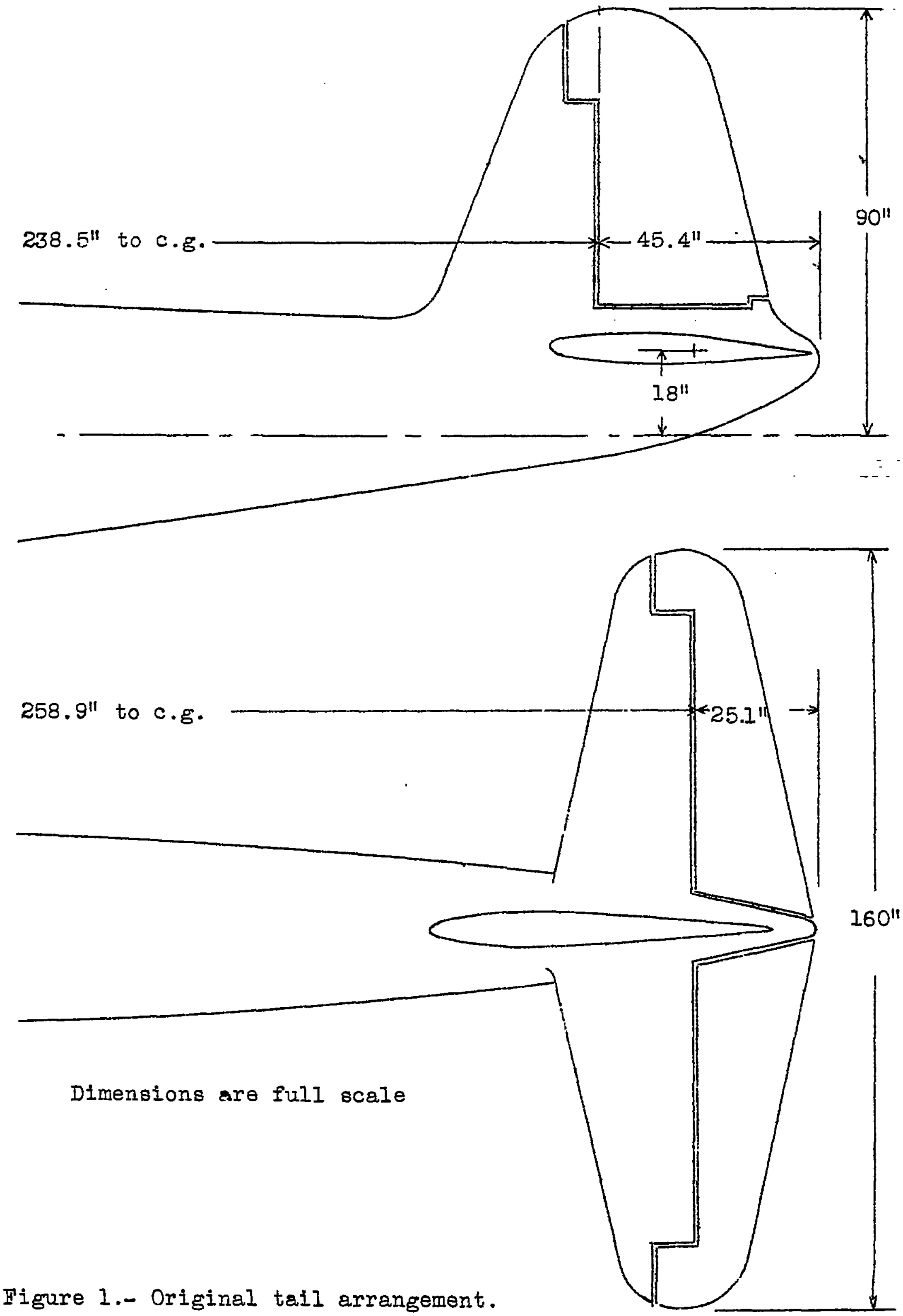

Figure 1.- Original tail arrangement.

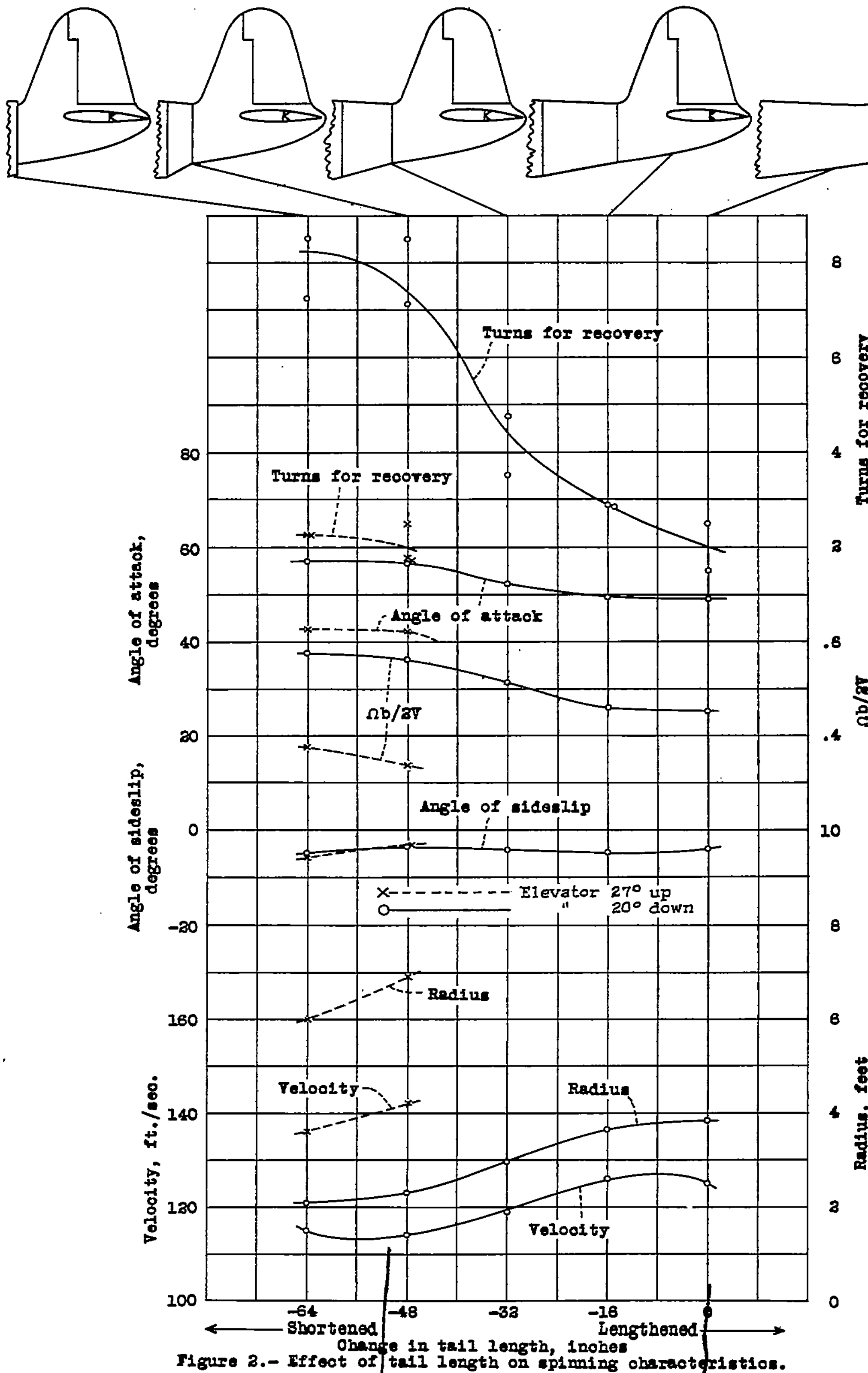

Figure 2.- Effect of tail length on spinning characteristics.

.38 .48

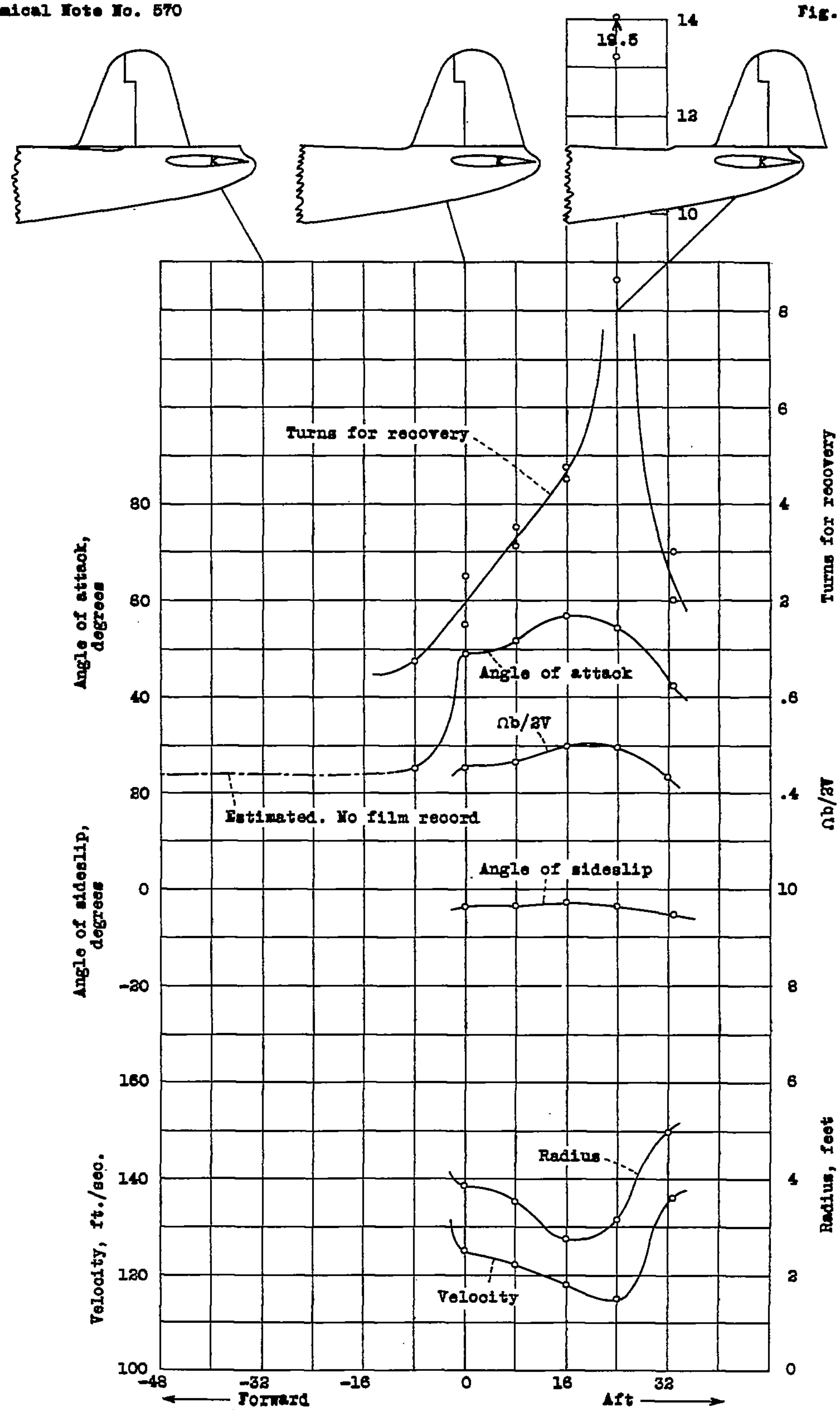

Figure 3.- Effect of position of vertical surfaces on spinning characteristics. Elevators down 20°.

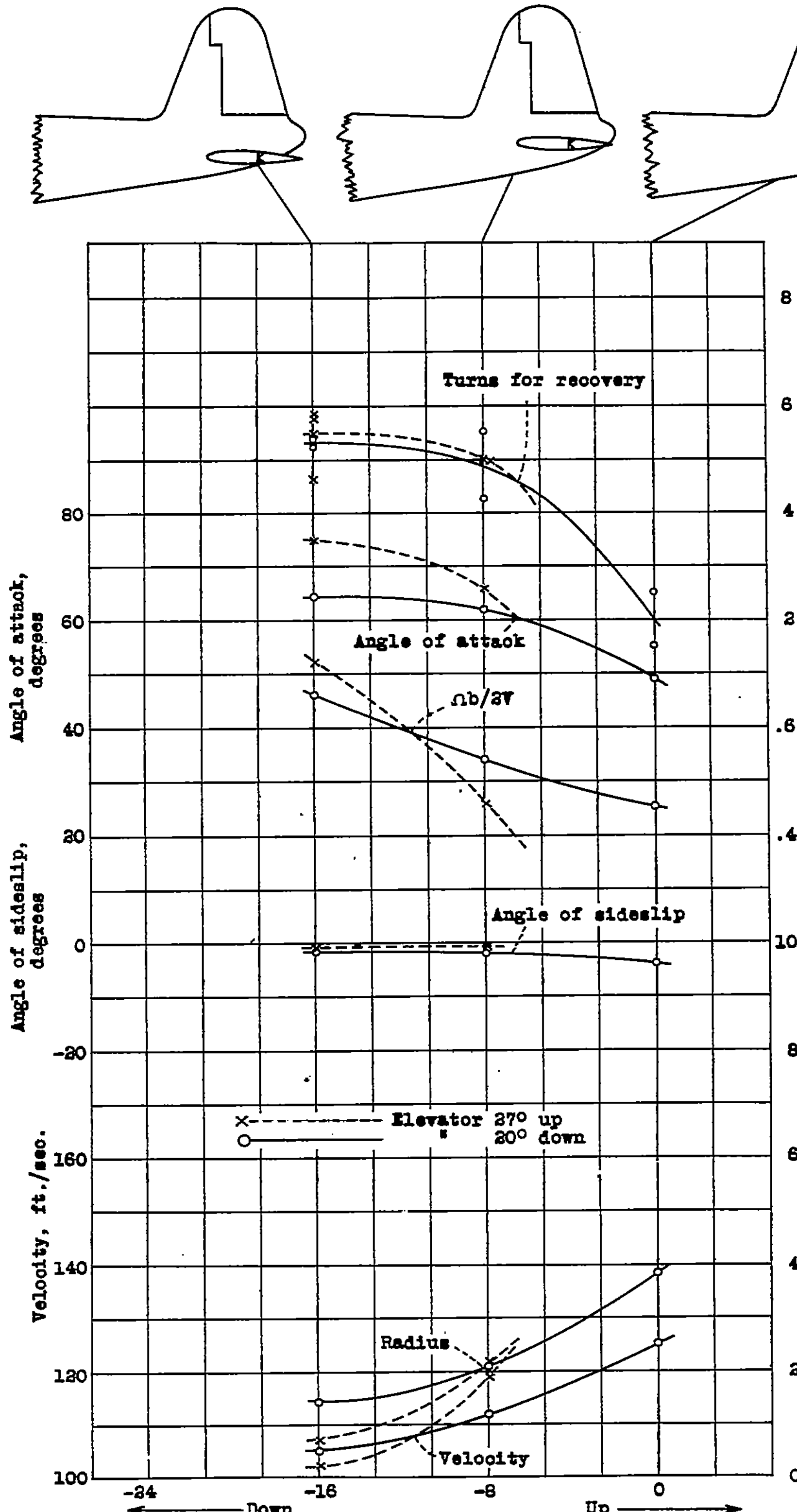

Figure 4.- Effect of position of horizontal surfaces on spinning characteristics.